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CONFERENCE OF EMPIRE METEOROLOGISTS, 1929.

AGRICULTURAL SECTION.

AGRICULTURAL METEOROLOGY

IN

F R A N C E.

AGRICULTURAL METEOROLOGY IN FRANCE.

In France two official organisations, entirely independent of each other, are engaged in the application of meteorology to agriculture. The first organisation is the National Meteorological Office of the Air Ministry and the second is the Agricultural Research Institute of the Ministry of Agriculture.

I. THE FRENCH NATIONAL METEOROLOGICAL OFFICE

by J. Sanson.

(Head of the Climatological Section, National Meteorological Office).

Since its creation in 1921 the French National Meteorological Office has been confronted with numerous problems which it has been necessary to classify in order of importance. The question given priority was the protection of aircraft and partly for this reason the activities of the Office were not at first specially directed towards agricultural needs. Agriculturists however have paid close attention to the improvement in methods of forecasting. The rural population has appreciated the arrangements made by the Office from 1922 onwards for the broadcasting over the whole country of information on the weather of the following day. There has been too great a tendency, however, among agriculturists to imagine that the forecasting of the probable weather of the morrow is the only service which meteorology can render to agriculture.

In 1926 a scheme of the Seed Selection Society of Galluis (Seine et Oise) was the starting point for a new orientation in the practical application of meteorology to agriculture. This Society asked the Office to recommend simple meteorological apparatus which would stand rough usage and could be obtained at a low price, which would allow the members of the Society and other agriculturists themselves to collect the climatological data which were needed in their investigations and for their crops. The Director of the National Meteorological Office recommended a number of pieces of apparatus which since that time have been used on a large number of agricultural holdings.[*] The typical meteorological station thus formed comprises:-

(1) For records in the screen, a "Polymetre", i.e. apparatus composed of maximum and minimum thermometer (Six et Bellani); a wet bulb thermometer forming, with the maximum and minimum thermometer, a psychrometer; and a (Piche) evaporimeter. These three instruments are on the same stand. The "Polymetre" is placed in a screen specially made for it.

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[*] To farmers of these holdings who send observations to the Office is given a pocket register for daily notes of meteorological and agricultural phenomena (see Appendix I).

(2) For measurements in the open.

(a) Measurements of Water: a pluviometer and a (Piche) evaporimeter. The latter can be kept constantly at the level of the plant by means of a slider.

(b) Measurements of Temperature. A maximum and a minimum thermometer placed a few centimetres above the soil; a sliding soil thermometer to record temperature from the surface of the soil down to a depth of 40 centimetres; four soil thermometers at fixed depths giving the temperature at 30 centimetres, 60 centimetres, one metre and 1½ metres depth.

(c) Measurements of Light. A (Jordan) heliograph and a (Bellani) actinometer.

In 1927 at the instance of the International Association of Wheat Seed Selectors, the Office decided to obtain from its observers complete phenological information on this cereal, such information having been furnished for nearly 50 years in a very summary fashion. In order to give these observers the training necessary for the work to be carried out satisfactorily, the Director of the Office drew up an account of the "Effect of Meteorological Factors on the Cultivation of Wheat". For the elucidation of this question a number of investigations were carried out on the effect of certain meteorological factors (especially precipitation) on the yield of wheat.

At the beginning of 1928, after obtaining advice from the Academy of Agriculture, the Office undertook an investigation into the damage caused in France to winter wheat and oats by the severe frosts of mid December 1927, and the effects of the absence or presence of a layer of snow on the soil. At the end of 1928 an enquiry was undertaken on the demand of the "National League of Defence against Crop Enemies", on the effect of the drought of the summer of 1928. An enquiry has recently been carried out on the damage caused to crops, in particular the vine, by the severe cold of February 1929 and the ensuing drought.

In order to draw the attention of agriculturists to the services which meteorology can render them, conferences have been held by the Director of the Office and his colleagues with numerous agricultural groups. "Meteorological lessons for the use of Agriculturists" are at the present time in preparation. The first volume, already issued, deals with instruments; the second and third volumes will deal with weather forecasting and climatology respectively. Further in 1928 and 1929, the Office exhibited, at the General Agricultural Exhibition in Paris, the meteorological apparatus which could suitably be installed on an estate or farm, with charts and graphs showing the relation between meteorological and agricultural phenomena. Thousands of copies of a questionnaire have been distributed to the agricultural community in all parts of rural France asking it to signify its wishes as to modifications or improvements to be made in the meteorological service.

The assistance given by the Meteorological Society of France in the dissemination of meteorological information in country districts must be mentioned. Its monthly illustrated review "La Meteorologie" is distributed free to all its members. This publication gives every month a general summary of weather in France, a description of its effects on agricultural work,

the conditions of crops, and an account of special studies carried out in agricultural meteorology.

Weather Forecasting. Since February 1922 the Eiffel Tower has sent out daily, at fixed times, weather forecasts by wireless; two of these forecasts are of particular interest to agriculturists viz. that in the morning which relates to the same day and that for the evening which relates to the night of the same day and to the following day. The forecasts are on the district basis, France being divided for the purpose into 12 districts. For each district information on the following is furnished:-

(a) General character of weather.
(b) Direction and force of wind.
(c) State of sky.
(d) Possible precipitation.
(e) Temperature variations.
(f) Phenomena dangerous for agriculture (frost, hail, etc.)

These forecasts relate to the twelve or eighteen hours following. The Office also issues every day at 13 o'clock from the Eiffel Tower a forecast of the probable weather in general for France up to the evening of the following day. Further, at times of urgent agricultural work (hay harvest, corn harvest, vintage), the Office indicates when possible, whether the prevailing weather is likely to continue for several days or not; but no long term forecast is made by the Office.

The duty of the Office is limited to making weather forecasts, and, logically, comments on the forecasts should be made by specialists of the Ministry of Agriculture working in collaboration with the Office. Such collaboration has not yet been obtained, but the "Radio Agricole Francaise" presided over by M.Ricard, former Minister of Agriculture, decided in 1927 to make such comments in co-operation with the Office for the benefit of agriculturists in the Paris district and in the North of France, who had asked for such comments by wireless. These comments are edited each day by M. Rabineau, President of the Agricultural Syndicate of the Paris District, and M. Vuigner, formerly Director of the Agricultural Co-operative Service of the French Society of Agriculturists. These two men have familiarised themselves with the forecasting methods in use by the Office and are in touch daily with its forecast services and they are supplied each afternoon, sometimes verbally and sometimes by telephone, with the most complete details of the atmospheric situation and its probable trend. Being thus in full possession of the facts, they can comment on the forecasts, make them suitable for the rural population and draw conclusions useful to the latter, enabling them to regulate their work on the morrow (e.g. cultural operations, carting, manure spreading, irrigation, harvesting). The commentators also refer to opportunities for carrying out preventive treatment when atmospheric conditions are favourable to the development of cryptogamic diseases, to the need for protection against frosts when these appear probable, and to the wisdom of increasing the dressings of certain manures to counteract either excessive humidity or drought. They also give more general advice adapted to the climate of each district, such for example as the use of a certain variety of wheat or the value of a catch crop. They thus render it possible for agriculturists to draw the maximum benefit from the forecasts. These Agricultural Meteorological Communiqués are broadcasted each evening by the Paris wireless, at a time varying with the season from 18h.30 to 20h. They apply only to the Paris district and the North of France for which districts the Meteorological Office at Paris functions as a

district station. When the Office has set up other district stations in France, it will effect the same liaison between them and the departmental agricultural services or the district agricultural syndicates, as has been established at Paris, and communiqués especially adapted to the needs of the different districts will be broadcasted by the provincial wireless stations.

When meteorological phenomena unfavourable to agriculture are announced in these communiqués, it is the business of those interested to take preventive measures. Protection is possible notably against spring frosts, either by the use of artificial smoke clouds or straw in vineyards or orchards, or by irrigation for certain kinds of grass land. Trials have been commenced in Champagne on the utilisation in combating frosts of orchard heaters similar to those used in the orchards of California. Another calamity it has been sought to mitigate is hail; "Niagaras" have failed, detonators (rockets) in vineyards have not been successful and the best method of protection against this scourge appears to be insurance. A study of the whole question is at present being carried out by the National Meteorological Office.

Failing reception by wireless of the forecasts, agriculturists can find them in their daily papers; but in this case agriculturists have expressed a wish for the forecasts to be accompanied by maps indicating the atmospheric situation. The Office is, therefore, studying at the present moment the possibility of transmitting meteorological charts each day by wireless.

Meteorology in Practical Agriculture. It follows from what has been stated above that the application of meteorology in practical agriculture is not the province of the National Meteorological Office, but that of the different services of the Ministry of Agriculture. Nevertheless, certain stations of the Office (Tours, Dijon, Montelimar etc.), carry out researches of an agricultural character. The Office does not possess agricultural experimental stations properly so called, but it communicates the results of meteorological observation from about 1,500 stations which it receives each month, to all those who ask for them, and in particular to seed selection stations, agricultural syndicates, departmental agricultural offices etc. Further, each of the meteorological stations directly dependent on the Office communicates to it, weekly, a short note on the state of crops in its district, and by means of these notes the Office is able to indicate, in its monthly summary of weather in France, the general influence of the meteorological conditions of the month on agriculture.

In order to reply to certain demands, the Office has been led to make certain studies of an agricultural character, the results of which have been conveyed in charts exhibited at the Agricultural Exhibition; such studies are the relations between the meteorological factors of the year 1926 and the yield of wheat; the effect of the cold of December 1927 on wheat and oats; the effect of the rainfall from April to June on the production of wheat in the centre of France; but these studies, undertaken without collaboration with the interested agricultural services, are necessarily incomplete, and will only be of maximum usefulness when this collaboration has been secured.

For the same reasons, there can be no question of the Office drawing up crop forecasts, or of giving technical advice on the preventive treatment against a probable invasion of cryptogamic diseases. The Office indicates the meteorological conditions of the coming days; and it is for the interested

agricultural services to interpret them and to draw conclusions from them, for example the conclusion that vine mildew is probable. It is for the latter therefore to tell agriculturists to "spray". In the vine country a certain number of agricultural organisations make use in this way of the forecasts of the Office and give information on the treatment to be applied; for example the School of Agriculture of Montpellier, the Agricultural Warnings Station at Grande-Ferrade near Bordeaux, and the Direction of Agricultural Services of the Marne. Similar advice is given on potato blight and on the spread of anthonomus.

Experiments on the effect of atmospheric conditions on soils and on manures, on plant physiology, on the varieties of plants to be cultivated in a particular district, are outside the province of the Office, but the Office has been led, by the demand of the International Association of Seed Selectors, to draw up a chart of the average number of days on which in France, the temperature is each month below -10° or above $+33^{\circ}$. This has allowed the districts to be determined in which freezing and burning out of wheat are most to be feared, and in which in consequence it is necessary to cultivate resistant varieties. The Office has also drawn up charts of rainfall in the vegetative periods of wheat, and the Association has thus been enabled to draw up a chart of wheat climates in France in relation to temperature and rainfall.

Lastly, besides numerous climatological data given to newly settled agriculturists, data are supplied relating to the monthly and annual distribution of rainfall and maximum heights of water collected (for the construction of cisterns); to winds (for the construction of wind wheels); to extremes of temperature; and to duration of frosts and their intensity (for the installation of heating in glasshouses and forcing houses).

Phenology. Certain phenological information has been furnished to the Office by its stations. Owing to lack of precision in the data thus furnished, the Office is at the present time carrying out a study on this question in collaboration with botanists and experts of the Department for Waters and Forests, and the Scientific Committee of the French National Horticultural Society. As a consequence phenological gardens (in which plants having a common origin are grown) have been set up in proximity to the principal meteorological Stations.

It must not be concluded from this survey that it is necessary for the Ministry of Agriculture to create an 'agricultural meteorological service'. Such service would need a network of meteorological stations and this would duplicate the work of the National Meteorological Office which, as has been stated, possesses 1,500 stations whose daily observations are sent to the office regularly every month. In order that a meteorological service applied to agriculture should function in France in a manner profitable to agriculturists, liaison is necessary between the National Meteorological Office and the Ministry of Agriculture. The latter would only have to specify the particular points to which, from the agricultural point of view, the attention of observers should be directed (whether for health or insurance, for aviation or for agriculture the majority of meteorological observations to be made are practically the same); and then specialists of the Ministry of Agriculture should ensure the practical utilisation in agriculture of the meteorological data, uniquely possessed in France by the National Meteorological Office.

APPENDICES TO THE PAPER BY J. SAMSON.

I. Particulars of Pocket Register supplied to agriculturists possessing the National Meteorological Office typical meteorological apparatus: for noting, daily, meteorological and agricultural observations:

The daily meteorological observations are required to be made at the same hour each day, viz. 7 a.m. (or failing that, 8 or 9 a.m. - one hour later in "summer time") and are as follows:- Date, precipitation, evaporation, minimum and maximum surface temperatures, soil temperature at 40 c.m., insolation and radiation.

The agricultural observations are not required to be made at fixed times but as often as necessary in the course of the day, and are as follows:- meteorological phenomena which may affect agriculture (fog, dew, frost, hail, sleet, snow, storms), time of phenomena and an estimate of effect on crops; dates of sowing, tillering and earing of cereals, hay and corn harvest, vintage, and lifting of beets and potatoes, different varieties being separately distinguished. Dates of appearance or disappearance of cryptogamic diseases or harmful insects and of treatment.

The daily meteorological observations are required to be carried to monthly tables and totals and means calculated. A special form is supplied for transmission monthly to the Office of meteorological and agricultural data.

Particulars of storms and hail (on account of their importance to agriculture) are required to be immediately notified to the Office on a special form.

Instructions as to installation and reading of instruments are given in the "Meteorological Lessons for the use of Agriculturists": prices of instruments and further information in a "Note on Meteorological Observations in Agriculture"

II. Examples of Agricultural Meteorological Communiques broadcasted by the Paris Wireless Station for the Paris district and North of France.

Wednesday, 13th February, 1929.

On Wednesday 13th February, we shall have fine and very cold weather; the wind will be from the north-east; it will be rather strong in the morning, moderating in the afternoon. Minima of temperature of less than -18^{0} are expected. The National Meteorological Office expects this situation to last for some few days yet.

Today we will give our listeners an account of the work to be done on grass harrowing, maintenance and manuring. This year on account of drought, the harvest of fodder crops was very much below normal. Prices are at a level hitherto unknown. To remedy this difficulty as much as possible, farmers who can do it should make new grassland and also strive to improve the yield of existing grassland. In February wherever possible stones should be cleared away, mole hills spread and the surface levelled, irrigation channels cleaned, weeds removed, and manuring and harrowing carried out. On old grassland still in good condition bare places should be reseeded. This work should be

carried out immediately after harrowing. Seeds of vigorous and rapid growing grasses should be chosen, such as rye grass, brome-grass, and oat-grass. If pastures have been invaded by moss, this can be destroyed by spreading 300 to 400 kilos per hectare of flaked sulphate of iron. This spreading must be carried out before harrowing. When grassland is in good condition, stones should be cleared where necessary. Molehills should be levelled, ditches and irrigation channels cleaned, weeds removed, and manuring and harrowing carried out, clods of earth broken down and the soil levelled. In manuring grassland account must be taken of the botanical composition. Temporary grass containing leguminous plants in quantity do not need nitrogenous manures at any rate after the plants are established, for they draw all the nitrogen necessary from the air. It is sufficient in such case to apply super-phosphate (400 to 500 kilos per hectare) or basic slag with 150 to 200 kilos of potassium chloride or potassium sulphate or a corresponding dose of sylvinite.

Permanent grass consisting chiefly of graminae should be given nitrogen to stimulate the grass.

Friday, 1st March, 1929.

Tomorrow we shall have a cloudy or very cloudy sky with occasional snow showers. Wind will be from the north-east, and moderate; temperature will fall by 3° during the previous night with minima of 10°. The rigorous cold which we are undergoing should draw the attention of farmers to the urgent necessity of giving a large dressing of nitrogenous manures to wheat. There will certainly be very much wheat frosted and irretrievably lost, but it is highly probable that the amount will be less than appearances would lead one to believe. Past experience shows that farmers who have spread nitrogenous manures on frozen wheat have thereby been able to save the crop and obtain a satisfactory yield. Wheat which looks bad should not be hurriedly ploughed in as soon as the thaw sets in; after applying the nitrogenous manure two or three weeks should elapse. A winter wheat which looks hardly tolerable at this time may eventually give a better result than a spring wheat. As a quick acting manure is required nitrate of soda should be given in a minimum dose of 100 kilos per hectare; even 150 to 200 kilos should be applied in certain cases. Nitrate of soda can be replaced by nitrate of lime; thus 100 kilos of nitrate of soda can be given immediately and 75 kilos of sulphate of ammonia or cyanamide shortly after. But the earlier the nitrate is applied the more valuable it is. This is especially the case in the present year. If after the application of the nitrogenous manures it is really necessary to plough in wheat, the nitrogenous manuring will not be lost. Spring wheat or oats grown in place of the ploughed in wheat will be able to utilise the nitrogen.

II. THE AGRICULTURAL RESEARCH INSTITUTE OF THE MINISTRY OF AGRICULTURE

by M. Geslin.

(Head of the Central Station of Agricultural Physics and Climatology, Versailles, French Agricultural Research Institute).

Introduction.

The necessity for studies and research in physics applied to agriculture and for including in agricultural research the study of the effect of weather and climate has not escaped the attention of the Ministry of Agriculture which in 1912, set up a special service for Physics and Meteorology applied to Agricultural Biology (among other subjects).

To increase and intensify agricultural production, a complete scientific research organisation became necessary; and the Finance Act of 30th April 1921 created an Agricultural Research Institute with financial autonomy and with the duty (under the Ministry of Agriculture) of administering and directing all the Stations and Laboratories of that Ministry, among them the Agricultural Physics and Climatological Stations.

The Agricultural Physics and Climatological Stations.

Following results obtained from 1898 onwards in the Bordeaux and Montpellier districts in the use of meteorological data in district weather forecasting, and in the forecasting of plant diseases with a view to warning agriculturists, Parliament has from 1913 onwards granted the necessary funds for the maintenance of a net-work of district stations for Agricultural Physics and Meteorology. At the present time this net-work comprises the stations at Montpellier, Bordeaux, Versailles, Rennes and Antibes. These are administered by the Institute of Agricultural Research and are provided with the apparatus necessary to determine the meteorological conditions under which experimental work is carried out, whether chemical, pathological or genetical. It is intended to create an Agricultural Physics and Climatological Station near each district centre or failing this each such centre will be provided with specialists to carry out meteorological and physical observations, and to take part in the research undertaken at the centre: it will also be the duty of such specialists to determine as accurately as possible the agricultural climate of their districts. The programme of the Agricultural Physics and Meteorology Stations comprises research into methods for the utilisation of natural forces (thermal, actinic, electric, magnetic, radio active, etc.) in the growth of plants; methods for protecting crops against harmful weather (frosts, hail etc.); and the utilisation of meteorological observations in forecasting yields of crops and outbreaks of plant disease with a view to warning agriculturists.

Fundamental to the whole of this work is the study of the relation between the development of plants and climatic factors. This necessary preliminary study is at present carried out by all the Stations. This work is dealt with in the following pages and this paper concludes by indicating briefly the stage reached in research undertaken to solve certain particular problems in agricultural meteorology.

Effect of weather and climate on crops and their parasites.

This research comprises:-

1. The systematic study of those climatic factors on which plants are strictly dependent.

2. The systematic study of the development of plants.

Neither of these studies is complete without the other and the neglect of either would delay the attainment of useful results. Numerous agricultural data exist regarding yields of crops with indications of the different phases of vegetation: but the information available in such cases on the nature of the soil and sub-soil, manuring, exposure of plots etc. is usually very vague. On the other hand, numerous meteorological data are available, but usually in the form of annual or monthly averages which have only a small interest from an agricultural point of view when one seeks to define the effect of the weather complex, the role of each of the components of this complex, and the methods by which the best use can be made of the favourable factors, and the effect of the unfavourable factors reduced to a minimum.

Does this mean that these data cannot be utilised? The writer is of opinion that as a necessary preliminary, a reliable "material" must be created as much agricultural as meteorological from which one can reason with certainty. It is the business of the Agricultural Physics and Climatological Stations with the help of all the Agricultural Stations to undertake this task of creation of"material". A few years will suffice to collect a number of documents sufficient to permit of the application of mathematical and statistical methods in the study and the correlation of meteorological phenomena with the yield of crops. This "material" can only be created by certain methods of work appropriate to Agricultural Meteorology. It is necessary at the outset to define these methods. They can be divided into -

(1) Meteorological observational methods
(2) Biological observational methods
(3) Methods of correlation of climatic factors with plant growth.

(1) Meteorological Observational Methods.

Among the climatic factors affecting the development of a given plant, certain have a predominating influence, such as water, warmth, light. Certain of these phenomena such as air temperature and precipitation are already regularly studied in general meteorology; others such as humidity, evaporation and secondary sources of soil humidity are only rarely studied. For the first kind of observations it will suffice to adapt to the needs of agricultural meteorology the investigational methods already employed in general meteorology. For the second class of observations it is necessary to create observational methods and the necessary apparatus. Finally, for each class of observations the data must be defined which it is necessary to collect, viz. those which seem to characterise best the climatic factor considered from the point of view of its effect on the development of plants. In order to make these conceptions clear, two examples, air temperature and soil humidity, will be taken.

Air Temperature. In climatology one ordinarily defines air temperature for a given day by its maximum, minimum and mean. The mean is sometimes calculated mathematically, sometimes more simply by taking the arithmetic mean between the maximum and minimum. It is apparent that the latter cannot be of use in agricultural meteorology since the same mean may result from a high maximum and a low minimum, or from a low maximum and a

high minimum. The knowledge of extremes of temperature for a given day is, however, insufficient from the agricultural point of view if we have no information on the successive temperatures during the course of the day, i.e. on the duration and the relative intensity of cold or warm periods. The same holds good when we considered a period of several days.

M. Chaptal at Montpellier has proposed to record each day the number of hours during which temperature is between 0° and 5°, 5° and 10° etc. M. Geslin at Versailles is also at work on this problem by a method which will better define favourable and unfavourable temperatures for any plant. In the absence of sufficiently precise data on the zeros of vegetation for each plant for the various stages of its development, it is difficult to define 'favourable' or 'unfavourable' temperatures.

Let us take wheat as an example. The sowing is always done round about a certain date and the same is true of harvesting. A priori, the date chosen for sowing is at a period of the year when the climatic conditions necessary for the development of the plant are realised, and it is implied that in the course of its growth the plant will encounter average climatic conditions corresponding to its successive needs. Now the average climate of a district is defined by what meteorologists call "normals", i.e. averages obtained from observations over a series of years. In agriculture, however, there are no normal years, and it is the differences (positive or negative) of the different climatic elements from the normals acting simultaneously or successively which condition the life of the plant and make the yields good or bad.

Suppose that we have determined for a given decade the normals of temperature, that is to say, the averages over a large number of years of maxima, minima and means. Let us call these normals Mx, Mn and My. We then find three intervals of temperature each having a precise significance. The interval from Mx to Mn corresponds to the zone of normal temperatures more or less favourable to the development of a plant according to the distribution of these temperatures about the mean My. At temperatures below Mn there will be a zone of temperatures abnormal by deficit; at temperatures above Mx there will be a zone of temperatures abnormal by excess. The effect, good or bad, of the temperatures comprised in these last two zones will depend on the one hand, on the difference in absolute value between these temperatures and Mx and Mn, and on the other hand of their duration. We can easily measure the duration on the thermograph chart. Knowledge of the daily maximum and minimum will enable the importance of a temperature comprised in the two intervals considered to be determined.

It is obvious from this example that, side by side with the notions of quantity which alone concern general meteorology, it is necessary in agricultural meteorology to introduce notions of duration and distribution of the phenomena. The study of each of the climatic factors should be undertaken from this triple point of view.

Rainfall. Mr. Chaptal has shown that the study of the rainfall of a district is not sufficient for an account of the conditions of dryness or humidity under which crops are placed. The total annual amount of water received, its seasonal and monthly distribution, the number of rain days, the duration and intensity of falls etc. are data obtained in general climatology and are insufficient for the needs of agricultural climatology. Knowledge of the humidity of any soil is only of a very limited interest from an agricultural point of view, if the physical condition of this soil is unknown or at least its maximum capacity for water

(water contained in 100 grams of dry earth when all the spaces, and the pores of the particles themselves are full), and its minimum capacity (water retained by drained soil). These two capacities are very variable according to the kind of soil. The maximum capacity rises from 45% for coarse sand to 155% for humus and the minimum capacity from 18% for coarse sand to 116% for humus.

It is difficult to determine the figures for maximum and minimum capacities of different soils for water under natural conditions The maximum capacity corresponds well with the case where the water, having pushed out all the air, fills, in consequence, all the empty spaces; but the minimum capacity escapes definition because a soil (principally in the neighbourhood of the surface) experiences continual variations in its content of water. These variations are due to the movement of the circulating air, to the heating and cooling of this air, to itshumidity to rainfall and to the condensation of dew. From the practical point of view it is necessary to know, for a certain soil, the quantity of water which can in each case ensure the best growth of each plant at the different stages of its vegetative cycle. It is generally assumed that the optimum quantity of water for the good growth of plants is from 40% to 60% of the maximum capacity, and that plants ordinarily suffer when the soil contains less than one-third or more than 80% of its saturation value. If we can determine the humidity of any soil and express this as a percentage of its maximum capacity for water, we shall obtain a series of data interesting from the agricultural point of view. Unfortunately, no process for measuring soil humidity is yet in practice. While the work of perfecting an apparatus for measuring soil humidity is proceeding an attempt can be made to solve the problem by means of vegetation boxes. A study of this kind is being undertaken at the Central Agricultural Physics and Climatological Station at Versailles.

(2) Biological Observational Methods.

These have two aims:-

(1) The biological analysis of the local climate (phenological observations).

(2) The study of the growth of crops to determine the action of climatic factors (ecological observations).

These methods have been set out in detail in the Annales de la Science agronomique (January-February 1927).[x] The essentials, only of these methods will be given here.

A. The necessary living material.

Research towards the solution of the problems set out above requires:-

(1) A collection of perennial plants, either wild or little modified genetically, indigenous for choice. Their annual growth must be studied as a function of variations in climatic factors.

(2) A collection of perennial plants to study the biological intensity of the autumn, winter and spring frosts.

(3) A collection of varieties of plants commonly cultivated in the district, for a comparative study of the stages of vegetation in each.

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[x] (See monthly Crop Weather report of the Ministry of Agriculture for December 1927).

(4) A small botanical garden to study the growth of weeds, of crops and the growth of the principal meadow plants.

(5) An experimental field for the purpose of determining the influence as a whole of climatic factors on production, of analysing the dependence of growth on these factors, and of determining critical periods in relation to favourable or unfavourable effects.

(6) At the same time fungus and other diseases must be studied as closely as possible in order to note the effect of adverse meteorological elements such as frosts.

B. Biological analysis of local climate - Phenological Observations.

In the first place a general and annual analysis of local climate must be made to establish seasonal variations in the weather, not merely to determine the nature of the local climate, but also to compare climates of different stations. It will be necessary to grow a series of shrubs of the same origin (i.e. immediate genetic origin and not merely the same geographical origin), in order to note the stages of vegetation; brairding, leafing, flowering, (first, full, last), ripening, leaf colour change, leaf fall. The observations of course, must always be made on the same individuals.

The seasons can be described in the following way (Pfaff system):

Before Spring - Beginning of flowering of the Hazel (female flowers).

Spring - 1st Period - Beginning of leafing of the Horse Chestnut, Birch, Lime; beginning of flowering of the Maple, the Sloe and Red Currant.

2nd Period - Leafing of the Birch and Black Poplar; flowering of Lilac and Hawthorn.

Beginning of Summer - Flowering of the Lime and the Privet; commencement of ripening of Red Currant and Mountain Ash.

Middle of Summer - Ripening of Elder and Viburnum.

Beginning of Autumn - Ripening of Privet and of Horse Chestnut.

End of Autumn - Change of colour of leaves of the Maple.

Beginning of Winter - Fall of last leaves of Black Poplar.

It is evident that to all these kinds, which can be grown almost everywhere, can be added kinds suitable to local climate, for example; Pomegranate (Punica Granatum L.), Holm Oak (Quercus Ilex L.), or even Eucalyptus (Eucalyptus globulus Labill.)

In addition, it is very useful to add some plants which are not shrubs butwhich are noteworthy for their sensitiveness to the cumulative effect of climatic factors, for example: Snowdrop (Galanthus nivalis L.); Yellow Crocus (Crocus aureus), Coltsfoot (Tussilago Farfara L.); Pheasant's-eye Daffodil (Narcissus poeticus L.); Leucanthemum vulgare Lamk.; Brown Radiant Knapweed (Centaurea Jacea L.); Lilium candidum L. In these cases it is sufficient to note the progress of flowering.

Analysis of climate made by means of the plants noted above will enable one to predict the lateness and the length of season in space and time. Biological analysis of the climate will be completed by observations of plants chosen with a view to estimating the effects of frosts.

C. The relation between climate and plants. - Ecological observations.

In the preceding section the specific type, or more exactly, the form nearest to it, has alone been envisaged. The most suitable measures have been sought to determine the climate from the thermal point of view. It is necessary, however, to obtain practical advantages quickly.

In agriculture we cultivate not species but varieties, it matters little whether they are pure or hybrid varieties. What we must, therefore, find out are the differences between them so far as concerns variations in the stages of vegetation (appearance above ground, leafing, flowering, ripening, end of vegetation). In the case of the vine, apple tree or wheat, differences between varieties are so great that nothing can be attained by synthesising the results if the varieties are not known; in each case it is clear that the success of cropping lies in the best adaptation of the variety to the climatic conditions of the district.

Where the principal crops are grown the experimental ground should comprise the orchard, the meadow and the field. No account need be taken of the garden because conditions there are so artificial that they must form the subject of a special study. MM. Ducomet and Crepin have indicated the observations that must be made in each case. Those on wheat can be taken as an example:- The Field - First of all its lay out. This should be based on the area of homogeneous soil, the plants it is desired to observe and the rotation to be adopted. The different plots should have an area of approximately 1 are (about 120 square yards). Cultivation will have to be done with the spade. As regards the actual plants, the crops of the district must serve as a guide. Sowing. Sow in lines as far as possible. Use seed shelled by hand and untreated seed in order not to affect artificially the germinating capacity. Use for all plants the same quantity of seed per unit of area (i.e. the same number of germinable seeds). Germinating capacity must therefore be tested. Note the percentage. Manuring and Maintenance. Use the same manuring both basic and supplementary; keep the land as free from weeds as possible; do not use chemical means for destroying weeds for fear of affecting yields. Observations on Wheat. Date of sowing, number of seeds to the metre row. Distance between rows. Appearance above ground of the growing points. Unfolding of the first leaf; Number of plants per unit of length; Beginning of appearance of fourth leaf, number of plants per unit of length. Tillering, beginning: appearance of third leaf on the first tillers. Earing; beginning of the swelling of the sheaf of the last leaf but one; beginning of emergence of ear (measure the average height in the field), ear completely emerged. Flowering beginning, full, end. Average height. Commercial ripening, (the grain cut with the nail without crushing) date, average height of plants, number of ears per square metre, average weight of ear, number of ears of a greater weight than the average for the year, average and percentage weights, number of ears of a smaller weight than the average for the year, average and percentage weight, average number of grains per spikelet in the middle of the ear, (count two stages of spikelets). Weigh the gross yield of the sample, grain and straw. Weigh grain separately to obtain the percentage. Determine the total number

of seeds per unit of weight. In the same way determine the number of marketable seeds (obtained by sifting with a No.9 screen); find the relation between number and weight. Deduce weight of 1,000 total seeds and of a thousand marketable seeds. Deduce the number of total seeds and marketable seeds per unit of area.

In this way one can calculate the effect of the year on the straw, the number and size of the ears, the setting and the seed production. Comparison of the yields from the different plots should be calculated, as a percentage above and below the average. The same should be done for the percentage of grain in relation to the total crop, for the weight of a thousand seeds, and the number and weight of the ears. These comparisons will show the variables which are most influenced by the rotation and by the year.

Remarks concerning the observations.

a) Counts. Repeat several times, at least thrice. It is recommended to make them per unit of length in order to facilitate operations. They can be calculated per unit of area after determining distance apart of rows.

b) Height of Cereals. This will be measured to the beginning of the top of inflorescence; beards are not included.

c) Flowering. The emergence of the stamens will allow the progress of this phenomenon to be followed. Examine preferably in the morning for wheat. Examine the leading inflorescences for the beginning, and the secondary inflorescences for the end. Full flowering is indicated by the maximum of stamens visible at the same time on the leading inflorescences.

d) Weeds. Note their importance in the crop, their appearance and their stage of development at the time of hoeing.

e) Diseases. It is necessary to follow their evolution as a function of the weather and of the state of development of the host plants, to determine the action of each on the yield (percentage loss). The notion of real or gross yield must be completed by that of the physiological yield. The real or gross yield (i.e. the quantity effectively harvested per unit of area) is conditioned by the direct intervention of both meteorological and disease factors. The physiological yield corresponds with the production conditioned by normal meteorological factors alone.

f) Direct Meteorological damage. It will be readily understood that adverse phenomena such as frosts, hail or drought and phenomena connected with meteorological factors such as the lodging of cereals, must be carefully noted and their influence on yield must be determined.

(3) Methods of correlation between climatic factors and the growth of plants.

The only practical method of comparison, if we consider the vegetative cycle of a variety of any plant for any year and for any place, is the graphical method. If on the contrary we consider a particular vegetative stage of a variety of any plant (a critical period for example) we must complete the graphical method by the employment of 'correlation' methods. These latter require a long series of data not yet available in France. Examples of the graphical method may be given.

Physico-meteorological observations and phenological observations enable a graph of the weather to be constructed which we will call the reference graph of the weather. It will take the form of a graph with several curves, one for each important phenomenon studied, characterising the local climate from the point of view of physics and biology. The more properly ecological observations will allow a series of ecological graphs to be drawn, each of the development of a plant or of a given variety. These different graphs will be drawn in such a way that comparisons can be made by simple superposition of the ecological graphs on the weather graph. The value of the deduction from these graphs will depend above all on the quality of the data used in their construction. Thus the possibility or impossibility of determining the relations between climatic factors and the yield of crops, will depend on the value of the observational methods whether physical or biological that have been employed. The study of these methods (which are proper to agricultural meteorology) at present forms the basic programme of the agricultural physics and climatological stations of the Agricultural Research Institute.

Some particular problems of Agricultural Meteorology.
Present position of research.

Resistance of Wheat and Oats to cold.

A study of this question has been undertaken since 1927 by crop improvement stations. It will be carried out in close collaboration with the agricultural physics and climatological stations. The following methods could be used to determine the resistance to cold of pure varieties of wheat or oats or hybrids: (1) Indirect methods (sugar content, osmotic pressure); (2) Use of artificial cold: (3) Use of natural cold.

Up to the present only the action of natural cold has been observed. For a more complete study of the action of cold to be carried out, low temperature chambers have been installed at the Central Agricultural Physics Station of the Agricultural Research Centre at Versailles. A large chamber (2 cubic metres) set aside for trials for resistance to cold, can hold more than 200 pans of 30 square centimetres. The present installation allows a range of temperature up to 25° C below zero. A constant temperature can if necessary be maintained in all parts of the chamber, or on the contrary an artificial climate can be created. The first trials on wheat and oats are being undertaken this year.

Frosts. Systematic research concerning frosts and methods of protection has been carried out, notably at Bordeaux and Montpellier.

Dew and secondary sources of soil humidity.

Research is in progress to determine: (1) the value and duration of nocturnal condensations (dew, mist etc.) as well as the time during which leaves remain wet during the morning. These questions are of highest importance both from the point of view of plant growth and cryptogamic diseases; (2) The importance of condensations within the soil.

Humidity and evaporation from the soil: transpiration of plants.

It has been previously shown in connection with the relation between crops and water that the most important factor is the quantity of water that the soil can give up to plants. In a systematic study of soil humidity, researches are being carried out at the Central Stations for Agronomy and Soil Biology at Versailles with a view to the construction of a practical measuring apparatus. Further, an installation of strictly isolated plant boxes is being set up at the Central Agricultural Physics and Climatological Station at Versailles and experiments will be commenced in the autumn of 1929.

Forecasting of Plant Disease Outbreaks - Agricultural Warnings.

It is known that copper treatments, to be efficacious against mildew and black rot of vine, must be preventive, that is to say, they must be carried out before the appearance on the organs of the vine of the lesions caused by the parasite. There is no treatment which can cure an invasion by mildew or black rot once it has commenced to show itself. It is not sufficient, however, to prevent the disease that treatment should be carried out before its appearance; it must take place during a certain period which precedes the appearance of the disease by several days. To be efficacious treatment must be made before the germination of the spores. A short time after their germination, the parasite takes possession of the tissues of the host, and has reached a stage of development such that it does not yield to treatment. The number and the intensity of outbreaks of these diseases are very variable in different years. Even in the same year the intensity varies according to district, nature of soil, variety of vine. In certain cases treatment can be dispensed with; in other cases numerous treatments are required to be carried out rapidly and with every care. In current practice no account is taken of these differences. Treatments are commenced at the same times and the same number of treatments are given every year on every soil for all vines. Extra treatments are given only when the disease has already ravaged the plants, but the extra care taken then is too late, and has no result. The basis of a rational system of treatment lies in the possession of knowledge which will allow forecasting of those cases in which the outbreaks will be early, frequent and important, and at what periods it will be necessary to spray to prevent their appearance. The technical methods used in drawing up warnings have been given in detail in the "Annales de la Direction generale des Eaux et Forets du Ministere de l'agriculture (Fascicule 48 - Rapport Capus - et fascicule 49 - rapport Ravaz)."

Following an agreement between the National Meteorological Office and the Agricultural Research Institute, agricultural warnings stations have ceased since 1923 to give weather forecasts and confine themselves to warnings concerning the dates of application of treatments. The issue of these warnings is carried out at present by the Stations at Bordeaux and Montpellier with the assistance of local stations distributed over the interested districts. The distribution of the warnings to subscribers is effected by wireless. In addition special notes containing information in detail and comprising a climatological summary are addressed to subscribers. The number of the latter (individuals or syndicates) is 113 for the Montpellier Station and 1,367 for the Bordeaux Station.